LONG RANGE TRANSPORT
OF ATMOSPHERIC POLLUTANTS
IN THE ATLANTIC PROVINCES

Recommendations for a Provincial Program

ENVIRONMENT NEW BRUNSWICK
ENVIRONNEMENT NOUVEAU-BRUNSWICK

CASIER POSTAL P.O. BOX 6000, FREDERICTON, N.B., CANADA E3B 5H1

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Prepared by: A.J. Spavold
Environmental Services Branch

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1.0 Introduction

Presently the air pollution programs of Environment New Brunswick are designed to monitor and control local sources of pollutants. However, a local approach to air pollution control ignores the effects of pollutants transported over long distances. There is increasing evidence that ions, heavy metals and organic compounds are being transported to the Atlantic Provinces, via the atmosphere, from sources hundreds and thousands of km. distant, resulting in increasing rainwater acidity and the deposition of toxic substances such as mercury, lead and polychlorinated biphenyls (PCB's).

The purpose of this paper is to discuss the issues pertaining to the long range transport of atmospheric pollutants (LRTAP), to indicate the severity of the problem and possible consequences to New Brunswick, to locate research interests and sources of data in the Atlantic Provinces, to identify information gaps and to recommend appropriate action for our department.

2.0 Issues

The LRTAP phenomenon and the negative effects of acid rain have been well documented in Scandanavia where reductions in rainwater pH due to pollutants transported from the industrialized UK and continental Europe have resulted in the deterioration of soils, reduced forest growth rates, increasing lake acidities and accompanying serious impacts to fish populations (Odén, 1976)

In North America outputs of pollutants such as sulphur have been increasing rapidly since the 1950's due to expanding industry and use of fossil-fuels to generate electricity. Technologies to contain pollutants at-source are usually rejected in favor of building higher output stacks, designed to reduce local levels of contaminants and to increase atmospheric dispersion and dilution. However, pollutants

removed effectively from one area may be received at another. For example, since the 1972 installation of a 381 m. stack at the Inco metals smelter at Copper Cliff near Sudbury, Ontario, local SO_2 problems have been virtually eliminated (Balsillie, pers. comm.). However a ERTS satellite photograph shows the undispersed plume travelling 150 km. downwind (Munn, 1976, fig. 1).

Central Canada produces over 4 million tons of sulphur oxides per year (approx. 10,000 tons per day) (Environmental Protection Service (E.P.S.), 1976). Emissions from the north-eastern United States are also very high (see figure 2). Increasing acidity of rainwater in Atlantic Canada suggests that the Atlantic Provinces may be receiving some of these pollutants. A study in Nova Scotia in 1957 indicated that the mean pH of rain near Kentville was 5.7, the pH value of "clean" rainwater in equilibrium with atmospheric CO_2. Recent data show much lower pH values, frequently below 5.0 (Atmospheric Environment Service (A.E.S.), 1977 a.). Sergeant and Zitko (1978) have recorded pH values as low as 2.99 with a mean of 3.84. As well, an increase in the number of days of reduced visibility due to haze has been recorded for the Atlantic Provinces, indicating an increase in photochemical pollutants (Munn, 1973, fig. 3). There is also evidence that the pH of some lakes in the Maritimes is decreasing (Wilson, pers. comm.). Several fish species including trout and salmon are adversely affected by a pH of less than 5.5 and the disappearance of these fish from the Tusket River in Nova Scotia and problems due to depressed pH levels at several fish hatcheries in that province have been attributed to acid rain and LRTAP (Watt, pers. comm.). Surveys in North America have documented adverse effects on fish populations in 75% of the high elevation lakes of the Adirondack Mountains of New York (Schofield, 1976).

Abnormally low pH values have also caused disappearance of fish in a large number of Ontario lakes. Beamish (1976) has studied the increasing acidity of Lake George in Ontario and described the local extinction of various species of fish including lake trout and small mouth bass and reductions in the reproductive success of others. It is hoped that a similar situation will not occur in the Atlantic Provinces.

Although the sources for these pollutants have not been definitively established (Technical Committee on the LRTAP, 1977) it is generally felt that most of our acid rain is transported from industrialized areas in Central Canada and the North Eastern U.S.A. Air over the Maritimes is usually of continental origin since in these latitudes the general air mass movement is from west to east (Department of Transport, 1962). As well, several studies of rainwater chemistry have shown that storms originating in populated areas have high concentrations of sulphate when compared with those originating at sea or from areas of low population (Shaw, 1979, Whelpdale, 1978). Also comparisons of rainwater pH and storm direction show that storms of lower pH generally come from the west and southwest (Curtis, 1975, Krause, pers. comm.).

The availability of data like these, the memory of the Scandanavian experience and the knowledge that reliance on coal-fired generation of electricity will probably increase, have engendered considerable research and discussion into the long range transport of air pollutants. However, despite the accumulation of information, the general feeling is that little is understood, especially since LRTAP involves multiple-source emissions and alteration of complex chemical cycles in the ecosystem which are themselves poorly understood.

3.0 Canadian Activities Relevant to the LRTAP Problem

In response to the need to coordinate research and organize information, a Technical Committee of the Long Range Transport of Atmospheric Pollution was set up by Environment Canada in 1976. In 1978 this committee drafted a LRTAP program for the Department of Fisheries and Environment calling for an emissions inventory for eastern Canada and the United States, the design and testing of models for LRTAP, studies of atmospheric processes such as the oxidation of SO_2, continued monitoring to establish possible trends and effects research on aquatic and terrestrial ecosystems. Several of these programs are directly relevant to the Atlantic Provinces and will be mentioned in more detail below.

Due to the trans-boundary nature of the long range transport problem, a Canada-U.S. Research Consultation Group for the LRTAP has also been established. This group is preparing presentation to the two governments in July, 1979. The report will define the problem, indicate possible emissions sources, estimate the magnitude, trajectories and deposition of emissions and map areas of potential sensitivity. A brief review of programs, information gaps and recommendations is to be included.

3.1 Activities and Research in the Atlantic Provinces

Regional Boards of the federal LRTAP Committee are responsible for collating and analysing data existing regionally and for making recommendations on future action. A report prepared by the Atlantic Regional Board, entitled Long Range Transport of Atmospheric Pollution- an Atlantic Perspective provides an inventory of major studies on LRTAP in the Atlantic Provinces up to the year 1977 (Table 1).

Since 1977, increasing interest in LRTAP has resulted in a large number of studies being initiated and many older studies being continued or updated. Almost every agency and institution contacted during the investigation for this report is either actively involved in acid-rain research, or is planning a program.

Research programs are basically of two types, those involved with monitoring rainfall acidity and/or concentrations of atmospheric pollutants and those involved in studying the effects of long range transport phenomena on terrestrial and aquatic ecosystems.

4.0 Monitoring Programs in the Atlantic Provinces

The data on atmospheric and rainwater chemistry obtained through monitoring programs can be used to establish rates of change and secular trends, to separate local and long range phenomena and to determine baseline conditions in anticipation of deteriorating air quality.

Unfortunately data are not always comparable due to variation in methodology and experimental design. The two main approaches to precipitation sampling, bulk sampling, or collection of all rainfall during a specified length of time, and event sampling, or collection of rainwater from a single rain-storm, give very different results. It is also important to consider the partitioning of a sample into wet deposition (pollutants contributed during rain or heavy fog) and dry deposition (fall-out of particulates and aerosols during dry-weather conditions). Several devices are available to sample precipitation, some of which are more efficient than others. Bulk samplers which collect both wet and dry deposition are useful as indicators of total inputs to a region, however, dry deposition can

severely affect results if the data is used to study rainwater acidification. Evaporation can also alter results in bulk sampling. Automated devices which have covers that open only during a precipitation event can be used to exclude dry deposition from a sample and also to avoid the necessity of manning a station to catch the onset of precipitatiion. The Cansap network uses the automated Sangamo-type sampler which collects wet and dry deposition separately on a monthly basis.

Another cause for variation in precipitation data involves the length of time between sample collection and analysis; while some researchers contend that at lower pH values, very little change in sample acidity occurs as long as biological activity is kept minimal, others have noted increases of as much as a unit of pH when field analysis is followed by measurement in the laboratory (Shaw, pers. comm.).

Several researchers have attempted to establish the relationship between acidity and ion concentration in rainwater and the origin of the pollutants by estimating the wind direction at appropriate elevations (Curtis, 1975) or by "tracking" the storm back through time. A simple "trajectory analysis" can be done using information on wind speed and direction to show what areas the associated air mass passed over prior to a precipitation event. A computer model for plotting storm trajectories, developed by the Atmospheric Environment Service (Young, pers. comm.) should soon be available for use.

4.1 The Canadian Network for Sampling Precipitation

As part of Environment Canada's program to study the long range transport of air pollutants, a series of stations has been established across Canada since 1977 to study precipitation chemistry. This Canadian Network for Sampling Precipitation (Cansap) supplements data collected by the World Meteorological Organization (WMO) pollution monitoring network established in 1975, and the Regional Background Air Pollution Monitoring Network. In the Atlantic Provinces the Cansap and WMO networks report from sampling stations at Sable Island (WMO), Kedjimkujik National Park, and Truro in Nova Scotia, Charlo and Saint John in New Brunswick and in Newfoundland, at Gander, Stephenville and Goose Bay, providing data on major cations, nitrate, sulphate, conductivity and pH. In the Atlantic region pH values are generally below 5.0, sulphate concentrations are in the range of a few mg/l, and nitrate ranges from concentrations of several tenths of a mg/l to a few mg/l (A.E.S., 1977). Shaw (1978) has compared data in the Atlantic region with that in other parts of Canada, concluding that acid rain is primarily an eastern North American phenomenon. As more data become available it is hoped that trends will be discernible.

4.2 Monitoring Studies in Nova Scotia

To supplement the Cansap data and provide a complete data base for Nova Scotia, the N.S. Department of the Environment set up a network of eight Cansap-type (Sangamo) samplers in 1977. Weekly samples provide data on pH (a low value of 3.38 has been recorded with most values below 5.7), major nutrients and heavy metals; use of trajectory analysis to track storm origins is also an objective of the program (Underwood, pers. comm.). Sangamos are also operated

in Nova Scotia by the Canadian Wildlife Service, two in Cape Breton Highlands National Park and one in Kedjimkujik National Park. This latter station is part of an intensive watershed study to be discussed below and reports a mean rainfall pH of 4.6 for 1978 (Kerekes, pers. comm.).

The Atmospheric Environment Service (Shaw, pers. comm.) uses a Sangamo for event sampling at the Head of St. Margaret's Bay; again pH values show acid rain inputs to the area. Aerosol sulphate data, collected at this station since 1978, show significant increases in sulphate in air masses that have passed over populated regions in central Canada and the eastern United States (Shaw, 1979). Environment Canada has also sampled aerosol sulphates in Nova Scotia and the other Atlantic provinces as part of their intensive Sulphate Study (A.E.S., 1977b).

Another set of stations for bulk sampling has been set up by J. G. Ogden (Dalhousie University, Halifax). He has also used plastic bucket samplers to monitor five precipitation events for comparison of inland and coastal stations and to estimate the extent to which marine aerosols provide buffering capacity against acid rain. (Ogden, pers. comm.).

Other sources of rainwater chemistry data in Nova Scotia include studies by W. Hart (Dalhousie U.) who has monitored sulphate and nitrate in precipitation and M. Case, also of Dalhousie, who has data on the heavy metal content of rain.

4.3 Monitoring Studies in New Brunswick

In this province, no network-type monitoring program has been established in addition to the two Cansap stations. Data from Cansap shows that New Brunswick's rain ranges in pH from 4.1 - 5.1, in sulphate from 1.2 to 7.1 mg/l and in nitrate from 0.1 to 1.8 mg/l

(A.E.S., 1977). Sergeant and Zitko (1978), Department of Fisheries and Oceans, St. Andrews, have found mean pH values of 3.84 and mean $SO_4^{=}$ values of 1.81 mg/l.

Krause (University of New Brunswick, Fredericton, pers. comm.) has done bulk precipitation sampling in conjunction with the Nashwaak River watershed study program and has shown a relationship between rainwater pH and wind direction at the time of sampling. As indicated previously, storms with the lowest pH originate from the west and south-west.

Rainwater chemistry has also been studied by Mahendrappa (pers. comm.) during fertilization experiments in the Acadia Experimental Forest; pH values were generally above 5.0, higher than those reported in other studies.

The Water Quality Branch (Inland Waters Directorate (I.W.D.), Environment Canada) in Moncton has gathered bulk and event precipitation samples for two years with the purpose of improving sampling methodology. A sequential sampler has been developed to study the changing chemistry of a precipitation event; in general the lowest pH and highest sulphate, nitrate and cation concentrations occur in the first part of the storm (Witteman, pers. comm.).

Data collected by Environment New Brunswick (Pollution Control Branch) as part of their regular monitoring programs may also be used to give some insight into the LRTAP question. S. Thorburn (University of New Brunswick, Fredericton) plans to study air quality data, using a form of trajectory analysis to determine whether or not long range transport phenomena are responsible for some of the episodic elevations of pollution levels in New Brunswick.

4.4 Monitoring in Other Atlantic Provinces

Preliminary results of a sulphur budget calculation for Nova Scotia show that 80% of the sulphur oxides produced in the province are exported via the atmosphere (Wilson, E.P.S., pers. comm.), indicating that Newfoundland and Prince Edward Island may be receiving pollutants produced by industry in New Brunswick and Nova Scotia. Neither Newfoundland nor Prince Edward Island currently has a provincial monitoring program, however, data for Newfoundland are available from the Cansap stations and early precipitation chemistry studies (see for example, Junge and Werby, 1958). Both provinces are interested in LRTAP and may become involved more fully in the future (B. Power, Nfld. Department of Consumer Affairs and the Environment, pers. comm.: P. DeRoche, P.E.I. Department of the Environment, pers. comm.).

5.0 Effects Research in the Atlantic Provinces

Studies on the effects of long range transport of pollutants usually concentrate on the influence of depressed pH or increased ion loadings to lakes, fish populations, forest soils or forest tree growth. Results of such research are often difficult to interpret due to the complexity of the systems involved, however with several years of data the Scandanavians have been able to show conclusively that their forests and fisheries are negatively influenced by imported air pollutants.

The Environmental Protection Service in Halifax (Wilson, pers. comm.) has gathered historical records of pH data from the 1930's to the present for a large number of lakes in the Atlantic Provinces including more than thirty from New Brunswick. Resampling of twenty of these (four in N.B.) has shown declines of at least a

pH unit in every case - one lake has a pH of 2.9. E.P.S. intends to varify some of the data and study fisheries information on population sizes, age-class structure and growth rates. If analysis justifies it, E.P.S. will request a resurvey of these lakes by Fisheries.

The Water Quality Branch at Moncton (I.W.D., Environment Canada) has also requested an analysis of all Naquadat Data for lakes in the Atlantic provinces to establish whether or not secular trends exist in the pH, conductivity, alkalinity or aluminium data; this should be available by early summer, 1979 (Cullen, pers. comm.).

Two major problems are inherent in this kind of data. Firstly, values for lake chemistry are not always comparable due to differences in methodology; in the 1930's, colorimetric methods were used as opposed to the more accurate electrometric methods used from the late 1940's to the present. Also, local pollutants rather than LRTAP phenomena can be responsible for lake acidification as shown by Watt et al (1979) who resampled 16 lakes in the Halifax area which had been studied in 1955 by Gorham (1957). The same study shows that sea-salt inputs can account for changes in sulphate and major cations.

The Department of Fisheries and Oceans in St. Andrews, N.B. has undertaken a program to study long term trends in the water chemistry and fish populations of ten lakes in southern New Brunswick (Peterson, pers. comm.). As well, laboratory studies are ongoing to investigate the tolerances of various fish species and the effects of acidity on various stages of fish development (Daye, pers. comm.).

Lake data will also be available as a result of a large watershed study being undertaken by Environment Canada in Kedjimkujik National Park, N.S. This project, under the direction of J. Kerekes (Canadian Wildlife Service), will look at the total effects of the long range transport of air pollutants on the watersheds of three lakes. This summer the Water Quality Branch in Moncton will conduct a two week intensive study on one of these lakes to access the effects of lowering lake pH on lake sediment chemistry. Interest in this subject comes from indications that a key factor in the low pH tolerance of fish species is accelerated release of toxic aluminium from the sediments as acidity increases.

The Canadian Forestry Service is undertaking a nationwide program to study the effects of LRTAP on the forest ecosystem. Initially the program will involve establishment of baseline data on forest productivity. It is anticipated that the program for the maritime region will be carried out in conjunction with a calibrated watershed project such as those ongoing at the Nashwaak River, N.B. or Kedjimkujik National Park, N.S. (Mahendrappa, pers. comm.).

The effects of acid rain on forest soils are also being studied by Dr. Krause, University of New Brunswick, in conjunction with his work on precipitation chemistry.

6.0 Other Sources of Information

Although not directly intended for use as such, data available from a variety of studies may be adapted for use by investigators of LRTAP problems. The following are possible sources of information:

a. data on lake and river chemistry collected by the New Brunswick departments of the Environment and Natural Resources (E.N.B. and D.N.R.) and the Inland Waters Directorate (I.W.D.). With

a few exceptions this information is stored on NAQUADAT and will be included in the I.W.D. report on trends (see above).

b. air quality data collected during the monitoring of local pollution sources. Control and background data may show the effects of LRTAP.

c. files on fish kills maintained by D.N.R. and E.N.B. contain unexplained occurrences that may provide information on LRTAP effects.

d. D.N.R.'s survey data on fish populations provides good baseline material for comparison with new information collected.

e. precipitation data collected for various projects. An example is rainfall data collected by the Department of Agriculture (J. MacMillan, pers. comm.).

f. watershed projects such as those carried out on the Nashwaak River (University of New Brunswick) and the Nashwaaksis River Basin (E.N.B.) provide a large inventory of background data useful to effects research programs.

g. soil surveys reports (New Brunswick Department of Agriculture and Rural Development) indicating the pH and buffering capacity (i.e. sensitivity to acid rain) of New Brunswick soils.

h. meteorological data recorded at various stations including airports provide long term records of haze, wind speed and direction and other climatological information.

i. public health data which might be used to indicate trends in pulmonary diseases.

7.0 Past Involvement in LRTAP By Environment New Brunswick

The earliest recorded involvement of our department with LRTAP is concurrent with the establishment of the federal Technical Committee on LRTAP in 1976 (Long Range Transport, File 8-5.6, Pollution Control Branch, Environment New Brunswick). At this time a questionnaire was circulated to provincial agencies to formulate an inventory of programs and information in New Brunswick related to the long range transport of atmospheric pollutants; the response was enthusiastic and results are on file. A LRTAP program was also recommended for New Brunswick in response to Environment Canada's need for additional data. To this end, E.N.B. collected data from stations in Saint John and Fredericton for inclusion in Environment Canada's Intensive Sulphate Survey (1977). At this time, Jim Young, E.N.B., suggested that a series of about 25 rainwater monitoring stations be set up across New Brunswick for analysis of storm events using meteorological information to trace the origins of the involved air masses. Such a program was not implemented, however E.N.B. has continued to input into Federal and Regional Boards of the Technical Committee on LRTAP. Drost (1977) noted that increasing ozone concentrations in Saint John might have some basis in long range transport phenomenon. In 1979, E.N.B. has undertaken to coordinate a project on LRTAP by S. Thorburn (see above).

Although federal agencies will be in the best position for coordinating programs, gathering information and taking corrective action on the LRTAP Problem, data gaps do exist and provincial groups can provide useful inputs to information. With the possibility that transboundary negotiations will be undertaken with the United States, the need for background data for New Brunswick as a basis on which to formulate policy becomes more important than ever. As indicated above, several research programs are underway in New Brunswick, however, data gaps do exist, particularly in the area of monitoring precipitation chemistry.

The need for cooperation is fundamental, particularly with regard to standardization of methodology and the comparability of results.

9.0 Recommendations for Action by Environment New Brunswick on LRTAP

In view of the preceeding information, the following recommendations are presented for appropriate action by Environment New Brunswick:

1. To ensure availability of data and to facilitate cooperation and communication between groups, a list of resource people and information on research programs and other involvements in LRTAP in the Atlantic Provinces should be retained in one location. The Atlantic Regional Board of the federal LRTAP Committee would be in an ideal position to fill this role, especially since they have already provided an inventory of research up to 1977; provincial representatives to the Board would be responsible for submitting and updating information from their own provinces. To this end, E.N.B. should update the information in this report from time to time.

2. A comprehensive study should be undertaken to determine the buffering capacity of New Brunswick soils and aquatic systems and the subsequent susceptibility of various areas to acid rain. Cooperation with the N.B. Department of Agriculture and Rural Development might be possible.

3. Due to the relative scarcity of monitoring programs in New Brunswick, and the need for data to confirm indications that the pH of our rainfall is decreasing, a monitoring program similar to that established by the Nova Scotia Dept. of the Environment is recommended. The scope of such a program would depend upon funds and man-hours available. E.P.S., Halifax (Lord, pers. comm.) has indicated that two Sangamo samplers could be made available on a short term loan; these could be located in two relatively pristine locations in New Brunswick (Mount Carleton has been suggested

as a particularly good location) to provide data additional to that supplied by Cansap, since the Cansap stations in New Brunswick are located in regions influenced by local pollution sources. Stations of this kind could be maintained with a fairly low man-hour requirement by E.N.B. inspectors or, with the cooperation of field staff from the departments of Tourism and Natural Resources. If data proved interesting, a more comprehensive program, using Sangamos or a cheaper efficient alternative, could be undertaken. It is also recommended that trajectory analyses be done on some of the data to supplement results obtained by Dr. Krause (U.N.B.).

Before additional monitoring programs are undertaken by any of the Atlantic Provinces some attempt at standardization of methodology should be attempted to ensure comparability of results. The Atlantic Regional Board should coordinate this effort.

4. With regard to methodology, the length of time between sampling and analysis for pH is of particular concern (see above). A short study into this question is justifiable and could be done quickly and easily.

5. Every effort should be made to standardize the methods used by E.N.B. to measure lake pH, since accurate long term records of lake chemistry will be necessary for LRTAP investigations. A variety of methods have been used, including Hatch Kit procedures not considered accurate for LRTAP studies.

6. If reports from E.P.S. and I.W.D. show trends in lake chemistry that may indicate deteriorating aquatic environments, E.N.B. should cooperate with E.P.S. in encouraging Fisheries to resurvey in anticipation of adverse effects to fish populations.

7. Dr. Peterson (D.F.O., St. Andrews) has indicated that a survey of aquatic vegetation in the lakes in southern New Brunswick for which chemical and fisheries data are being collected would be valuable as additional baseline material. Personnel of the Environmental Quality Section of the Environmental Services Branch could work cooperatively with D.F.O. to incorporate this study into programs for 1980. A resurvey of vegetation would be necessary in five years to establish whether or not trends exist in the data.

8. The LRTAP workshop to be held by the Atlantic Regional Board in Halifax in mid-October will provide an opportunity to discuss anticipated E.N.B. LRTAP projects with other workers in the Atlantic Provinces. Proposals for projects to be undertaken in 1980 should be prepared in time for this event and should also be presented to the Atlantic Regional Board for comments and suggestions.

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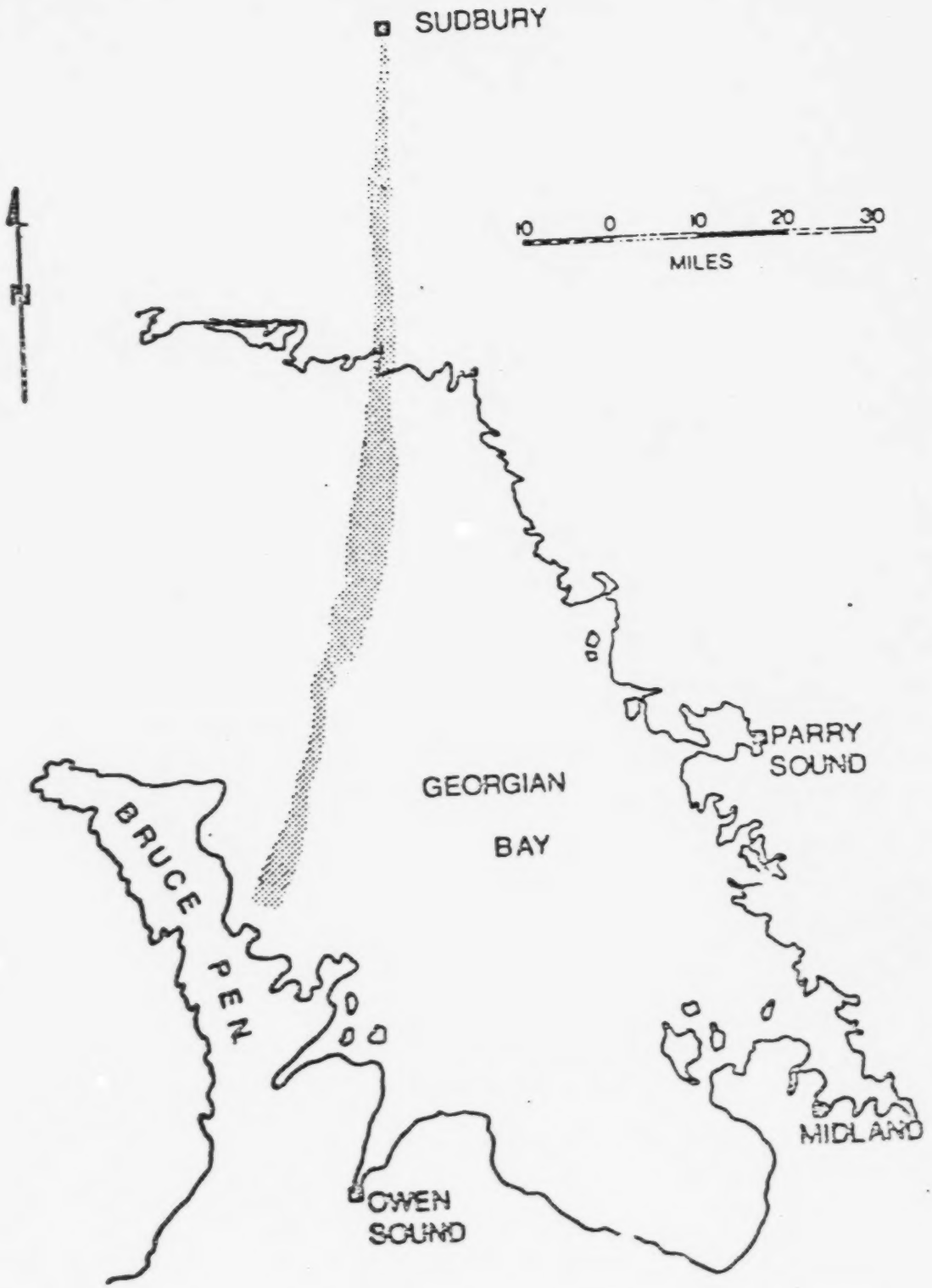

Figure 1. Copy of a satellite photograph showing the outline of a Sudbury smelter plume crossing Georgian Bay (Munn, 1976).

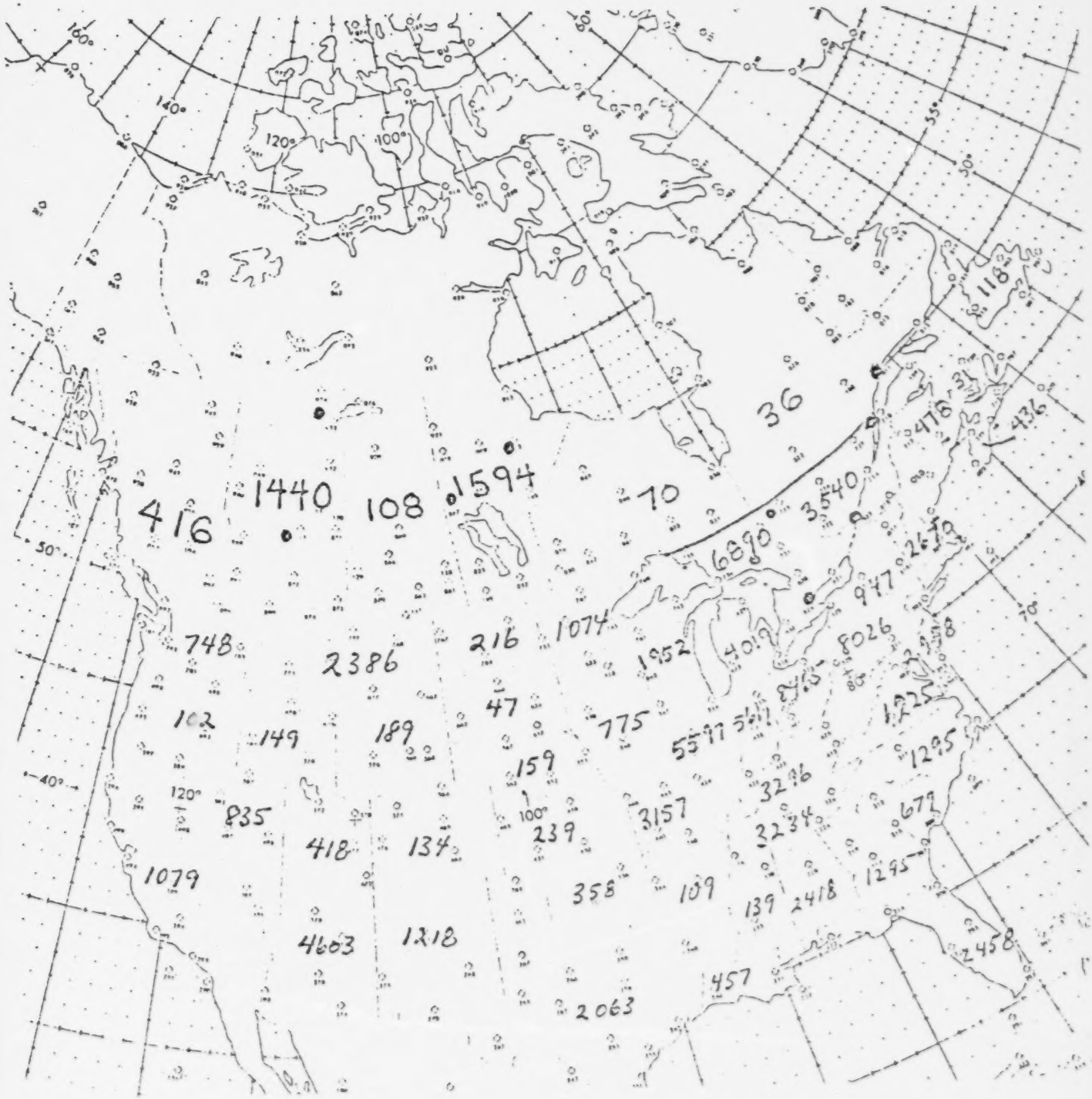

Figure 2. Mean daily SO_2 emissions (Metric tons) from anthropogenic sources in North America (McBean, 1977).

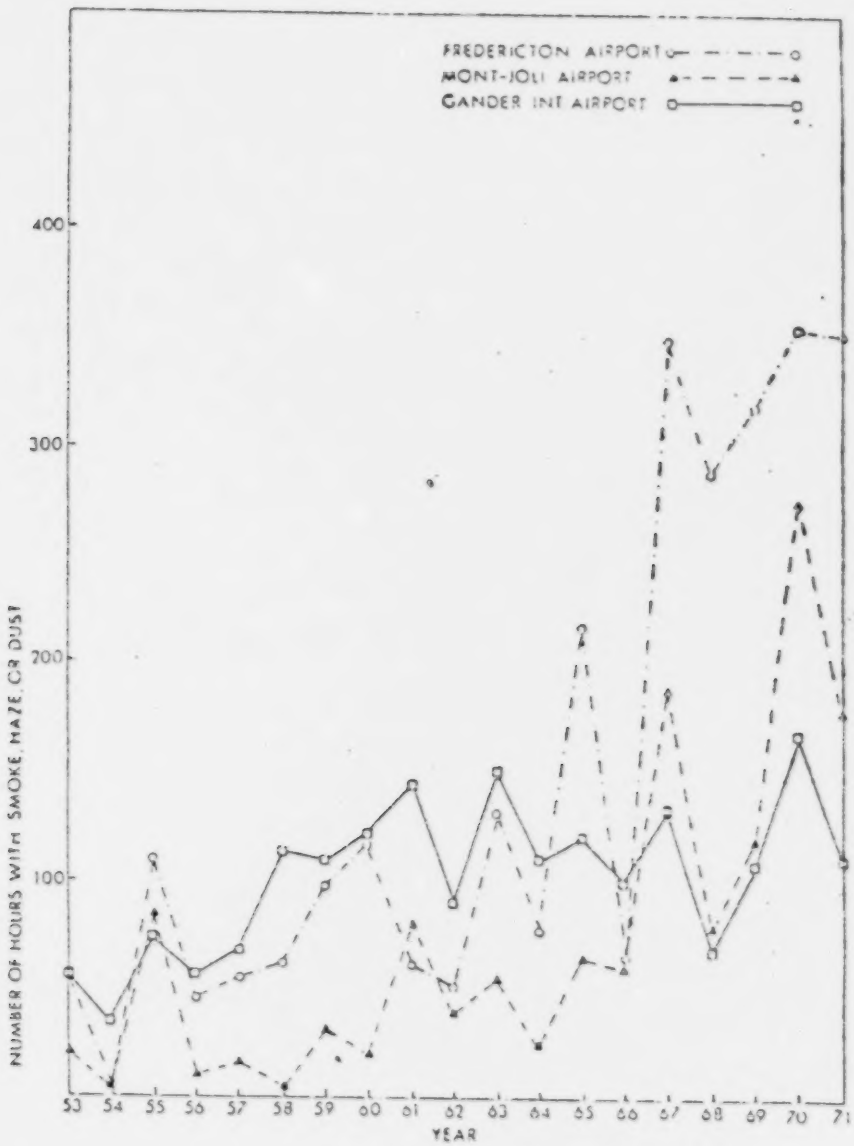

Figure 3. Secular trends in the number of hours of smoke, haze or dust at locations in the Atlantic Provinces for the months May to October for the period 1953-1971 (Munn, 1973).

Figure 4 - Locations of precipitation monitoring stations in the Atlantic Provinces.

TABLE 1: CHRONOLOGICAL LISTING OF PRECIPITATION QUALITY DATA IN AND NEAR THE ATLANTIC REGION

DATE	LOCATION	SAMPLE TYPE	PRECIPITATION	RESULTS	pH	SO_4 mg/l	NO_3 mg/l	Hg mg/l	PCB	SO_4 load	NO_3 load	REFERENCE
June 1952 - May 1954	Kentville, N. S.	bulk, monthly composite	all	mean	5.7	3.0	0.49	--	--	9.1 kg/hectare/year		Herman and Gorham (1957)
				winter rain	6.7	2.1	0.50	--	--			
		event	snow	snow	5.6	0.9	0.31	--	--			
July 1955 to July 1956	Stephenville, Nfld.	precipitation only, monthly composite	all	annual mean	--	0.92	0.31	--	--			Junge (1958), Junge and Werby (1958)
July 1955 to July 1956	Caribou, Maine	precipitation only, monthly composite	all	annual mean	--	2.74	0.44	--	--			Junge (1958), Junge and Werby (1958)
June 1964 to May 1966	Hubbard Brook, New Hampshire	bulk, weekly composite	all	minimum		1.4	0	--	--			Fisher et al (1968)
				maximum		6.7	3.1	--	--			
				mean		3.4	1.1	--	--			
				winter mean		2.8	1.5	--	--			
				summer mean		3.8	0.9	--	--			
October 1965- May 1966	Hubbard Brook, New Hampshire	precipitation only, weekly composite	all	minimum	--	1.4	0.6					Fisher et al (1968)
				maximum	--	7.6	7.3					
				mean	4.1	3.7	2.5					
September 1965 August 1966	Houlton, Maine	bulk, montly composite	all	annual mean	5.1	3.24	0.24			24.6 kg/hectare/year	1.85 kg/hectare/year	Pearson and Fisher (1971)
May 1969 to October 1970	Central New Brunswick	bulk, event	rain	range	5.5-6.0							Mahendrappa and Ogden (1973)
October 1970 February 1971	St. Andrews, N. B.	precipitation only, event	all	mean over 9 events	--	--	--	0.11	--			Zitco and Carson (1971)
August 1972 - September 1973	Nashwack Watershed, N. B.	precipitation only, weekly or bi-weekly (summer observations only)	all	minimum	3.72	--	--	--	--			Curtis (1975)
				maximum	5.30	--	--	--	--			
				mean	4.2	--	--	--	--			

TABLE 1: CHRONOLOGICAL LISTING OF PRECIPITATION QUALITY DATA IN AND NEAR THE ATLANTIC REGION

DATE	LOCATION	SAMPLE TYPE	PRECIPITATION	RESULTS	pH	SO_4 mg/l	NO_3 mg/l	Hg mg/l	PCB	SO_4 load	NO_3 load	REFERENCE:
June - August 1972	Gulf of St. Lawrence	N/A	N/A									Ware & Addison (1973) (Note: PCB concentrati in plankton related to rainfa amount)
November 1972 to May 1973	Sydney, N. S.	bulk	all	mean at each location	5.17-5.7	2.8-8.0	2.38-6.5	--	--	2.23-7.37 kg/hectare/month	--	McKay (1975)
April 1975 - present	Sable Island, N. S.	precipitation only	all	monthly mean (1975)	4.3-6.0	1.8-4.4	0.2-1.4	--	--	--	--	Olson et al (1976)
	Shelburne, N. S.	precipitation only	all	monthly mean (1975)	4.3-5.2	0.3-4.0	0.1-1.0	--	--	--	--	
April - May 1975	NAPS Stations across Canada	Hi-Volume particulate	N/A	daily mean ambient concentration	N/A		MANY	DATA	REPORTED			DFE (1975)
Winter 1976	Saint John River Basin	Core of fallen snow	snow	minimum maximum	--	--	--	<0.1 0.2	--	--	--	Travers (1976)
July - August 1976	36 stations in Eastern Canada	precipitation suspended particulate $SO_4^=$	rain --	daily mean			MANY DATA	REPORTED				DFE (1977)
October 1976 to March 1977	Cape Breton Highlands National Park	precipitation only, event	all	minimum maximum	3.6 6.4	2.5 8.0	-- --	-- --	-- --	-- --	-- --	Kerekes (1977)

(Technical Committee on the LRTAP, 1977)